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EVOLUTION OF THE NASA INSTITUTION

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I must begin by telling you how humbling it is to speak to the NASA Alumni League about the history of this institution. All of you together have a wealth of memory and insights--earned through years of experience--that exceeds anything a single historian could record. The good anecdotes--bitter ones, sweet ones, inspiring ones--the best ones belong to you.

What I <u>can</u> attempt to offer you is perspective, the long view that we historians try to achieve. This historical perspective reveals patterns which, like the outlines of a machinist's template, help to account for many of the twists and turnings in NASA's institutional history and, perhaps, your own careers with NASA.

ORIGINS OF NASA

When the Soviet Union inaugurated the Space Age by successfully launching the first man-made orbiting satellite, Sputnik I, in October 1957, the administration of President Dwight D. Eisenhower and the U.S. Congress created the National Aeronautics and Space Administration (NASA) to orchestrate the United States' peaceful response to the Soviet challenge. NASA officially opened for business on October 1, 1958, with a complement of nearly eight thousand employees transferred from the National Advisory Committee for Aeronautics (the NACA). Established in 1915, the NACA for 43 years had conducted research in aerodynamics and aircraft structures and propulsion systems for both industrial and military clients.[1]

The NACA was informally structured and overseen by its Main Committee and various technical subcommittees. Its work in aeronautical engineering research was done largely by civil servants located at Langley Aeronautical Laboratory at Hampton, Virginia (est. 1917), Ames Aeronautical Laboratory at Moffett Field, California (est. 1939), the Flight Research Center at nearby Muroc Dry Lake (est. 1946; Dryden Flight Research Center after 1976), and the Lewis Flight Propulsion Laboratory in Cleveland, Ohio (est. 1940). Aside from its work in aeronautics, what distinguished the NACA as an institution was the ethos that came to permeate its laboratories. With its emphasis on technical

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[1] The NACA's closest precursors among Federal research laboratories were the laboratories of the Department of Agriculture (est. 1862), the National Bureau of Standards (est. 1901), and the Marine Hospital and Public Health Service (est. 1902). Not until the end of World War II would the Congress create a comparable institution--the Atomic Energy Commission (est. 1946)--which, however, relied largely on contracts with private organizations created to carry out its research programs. For a history of the NACA, see Alex Roland, *Model Research: The National Advisory Committee for Aeronautics, 1915-1958*, NASA SP-4103 (Washington, D.C.: U.S. Government Printing Office, 1985), and James R. Hansen, *Engineer in Charge: A History of the Langley Aeronautical Laboratory, 1917-1958*, NASA SP-4305 (Washington, D.C.: U.S. Government Printing Office, 1987).

competence for engineering research, evaluation of one's work by technical peers, and a collegial working environment thought conducive to engineering innovation, the NACA's research culture was poorly equipped to adjust to changing circumstances that bore upon its work in the 1940's and 1950's. Those changes are worth recalling here, because they are similar to the changes that would complicate life for NASA 20 years later. Like successive waves on a single ocean, they were all part of the same process.

BEGINNINGS OF CHANGE

The first change to come over the NACA was a gradual shift in emphasis toward development work. The NACA's credibility as the Nation's premier aeronautical research institution had been damaged during the 1940's by the progress Europeans had made in jet propulsion and rocketry. As a result, the military services, important NACA customers, successfully sought authorization to develop their own research and development capabilities. Not to be left out, the NACA agreed in the 1940's to several joint military and industry research aircraft projects--of which the Bell XS-1 is probably the best remembered. As a result, the NACA began a transformation from a research organization into a research <u>and development</u> organization.

The second change occurred as the NACA, its growing business matched by a declining ability to attract qualified personnel, began to rely increasingly on letting contracts to outside firms to get its work done.

By the mid-1950's, the NACA was receiving its requested appropriations and had recovered much of the confidence it had lost. But the organization was faced with a still more difficult challenge. That challenge marked the third change--the growth of centralized Federal administrative controls over all Federal organizations--controls like standardized personnel management, budgeting, procurement, and operating procedures. These controls began to be imposed upon the NACA by the Bureau of the Budget, the Civil Service Commission, and ultimately--of course--the U.S. Congress. Centralized mechanisms of public administrative control were resisted by the NACA, which also found itself in intense competition with the powerful Department of Defense (est. 1947) and threatened by the intrusive politics that accompanied expanded congressional oversight.[2]

THE NACA BECOMES NASA

The NACA was transformed in 1958 into NASA, an organization with a renewed and much enlarged mission. The committee structure which had administered the NACA was abandoned for an hierarchical and centralized management structure. The new organization still sought, however, to retain the discipline orientation of the NACA's decentralized laboratories, accentuating a tension between disciplinary interests and program organization that would persist through much of NASA's institutional life in the next 30 years.

Starting with the nearly eight thousand paid employees transferred to NASA from the NACA, by the end of 1960 NASA personnel rolls had nearly doubled to over sixteen thousand. The principal increases occurred largely at NASA Headquarters

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[2] For a detailed account of the NACA's (and later NASA's) struggles with the growth of centralized Federal administrative policies and organizations (e.g., the Bureau of the Budget, the Civil Service Commission, and congressional authorization and appropriations procedures), see Roland, loc. cit., and Nancy Jane Petrovic, "Design for Decline: Executive Management and the Eclipse of NASA," Ph.D. Dissertation, University of Maryland, 1982 (Ann Arbor, Mich.: University Microfilms International, 1982).

(where personnel more than tripled), and with the addition to the agency of the Army Ballistic Missile Agency (renamed the George C. Marshall Space Flight Center) and the new Goddard Space Flight Center in Beltsville, Maryland. The Jet Propulsion Laboratory of the California Institute of Technology, a contractor owned and operated facility involved in rocket research since 1936, was also transferred from the U.S. Army to NASA in 1958.[3]

A little over 80 percent of NASA's technical core--its engineers and scientists--thus held within its corporate memory the experience of working with the NACA, the Army Ballistic Missile Agency (ABMA), and the organizations from which Goddard Space Flight Center had drawn much of its personnel, namely, the Naval Research Laboratory (NRL) and the Naval

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[3] By the end of 1960, the old NACA laboratories and Marshall Space Flight Center accounted for 49% and 33%, respectively, of NASA's employees. (The Manned Spacecraft Center in Houston, Texas, was added in 1961 and the John F. Kennedy Space Center at Cape Canaveral, Florida, in 1962). The 157 personnel who had been working on the Navy's Project Vanguard, which became the nucleus of the Goddard Space Flight Center (est. 1959), were transferred to NASA in 1958 from one of the Navy's own in-house research laboratories, the Naval Research Laboratory. They were soon joined by 63 more who had been working for the Naval Research Laboratory's Space Sciences and Theoretical divisions. The next large group to transfer to NASA was the 5,367 civil servants from the U.S. Army's Ballistic Missile Agency (ABMA) at Redstone Arsenal, in Huntsville, Alabama. The ABMA had been essentially an in-house operation. The youngest NASA installations, the Manned Spacecraft Center (est. 1961 and renamed Johnson Space Center in 1973) and Kennedy Space Center (est. 1962), were initially staffed by personnel from Langley Research Center and the ABMA.

Ordnance Laboratory (NOL).[4] Each group would bring with it a well-established culture--the NACA and NRL groups, the culture of in-house engineering research and science, and the ABMA group, the in-house technical development culture of the Army's arsenal system.

In time, NASA's engineers and managers, most of whom had risen through engineering ranks, would experience the gradual erosion of the institutional discretion and the ethos of in-house technical competence that had characterized their previous careers with the NACA. To begin with, in the future they would work for a centrally and hierarchically managed organization, split into two tiers to accommodate functionally disparate research centers and program offices. Secondly, their executive leadership would be chosen for them on the strength of its political and managerial, as well as technical, experience. And as experienced public administrators, that leadership would, and did, yield to the scrutiny and controls imposed by the Bureau of

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[4] Robert L. Rosholt, *An Administrative History of NASA, 1958-1963*, NASA SP-4101 (Washington, D.C.: U.S. Government Printing Office, 1966). Source for Personnel Data: *NASA Historical Data Book, 1958-1968. Vol. I: NASA Resources*. NASA SP-4012. Washington, D.C., 1976. NASA Pocket Statistics, Washington, D.C., January, 1971; Personnel Analysis & Evaluation Office, NASA Headquarters, Washington, D.C., May, 1986. Personnel Data Analysis available in NHO.

the Budget, the Civil Service Commission[5], and the congressional authorization process.

MOBILIZING FOR APOLLO

After President John F. Kennedy issued his challenge to the Nation in May 1961 to send a man to the Moon and return him safely within the decade, NASA undertook a mobilization comparable, in relative scale, to that undertaken by the U.S. to fight World War II. The agency's civil service personnel rolls increased by a factor of three, while the men and women employed on NASA contracts increased by a factor of 10.[6] Likewise, NASA's annual budget increased an order of magnitude between 1960 and 1965, from roughly $500 million to $5.2 billion.

NASA was able to succeed with the Apollo program because it was able to recruit thousands of trained engineers in the 1960's. It could do so because no engine designed to

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[5] The Bureau of the Budget became the Office of Management and Budget (OMB) in 1970, while the Civil Service Commission became the Office of Personnel Management (OPM) in 1979.

[6] NASA Personnel in 1960: (C-S) 10,286; (Contractor) 36,500. NASA Personnel in 1966: (C-S) 33.924; (Contractor) 360,000. Increase = +300% C-s; +1000% Contractor. Total active U.S. military personnel in 1940: 1,215,969; Total active U.S. military personnel in 1945: 12,255,527. Increase = +1000%.

launch men to the Moon was as powerful as the engine of the Federal Government itself. With one eye cocked on growing joblessness and labor unrest that had followed demobilization after World War I, and the other on the languishing supply of scientists, technicians, and medical personnel as young men marched off to war or into the factories that would supply the front, the Congress passed the Servicemen's Readjustment Act (better known as the GI Bill) which, along with its Korean War counterpart, kept millions of veterans out of the job market and sent them to school instead. The GI Bill, combined with the military services' reserve officers' training programs, cooperative work-education programs, and the draft--with its exemptions and deferments for those in engineering school or working for the government in engineering fields--all generated in this country one of the great occupational shifts of the twentieth century.

The private sector provided even more scientists and engineers for Apollo than did NASA. Throughout its history, roughly 80% of NASA's budget has gone into procured goods and services, or contracts. The notion of relying on private industry and universities was not original, however, with

Administrator Jim Webb--though both necessity and good politics made him a natural champion of contracting out as the way of getting the agency's work done.

The military services had had the most experience with contracting, since they had acquired equipment and logistics support from the private sector since the early 19th century. More recently, it was the U.S. Army and U.S. Air Force, created out of the U.S. Army Air Forces under the Defense Reorganization Act of 1947 that created the Department of Defense, that had the most experience with contracting to the private sector. As a result of the Army's Manhattan Project and the ballistic missile programs managed by the Air Force's Research and Development Command, both services came to rely on private contractors for advanced engineering and development work--the Air Force going so far as to create the Rand and Aerospace corporations. In 1959, the General Services Administration authorized NASA to use the Armed Service Procurement Regulations of 1947, which contained important exemptions, tailored for research and development work, from the principle of making awards to the "lowest responsible bidder."

So it was that NASA mobilized for Apollo not by amassing a large complex of federally owned engineering and fabrication facilities or civil servants, but by contracting for the bulk of its hardware and R&D work, as well as support services, to the private sector.[7] Doing so had the obvious advantage of enabling the civilian space program to harness talent and institutional resources already in existence in the emerging aerospace industry and the country's leading research universities.[8] Contracting out had the additional advantage of distributing Federal funding, which was funneled through NASA's centers, around the country and, as a consequence, creating within the

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[7] One NASA installation, the Jet Propulsion Laboratory of the California Institute of Technology in Pasadena, California, would remain wholly a contractor operation.

[8] Since the beginning of the republic, Americans have shared a widespread distrust of "big government." This mistrust was translated into presidential and congressional politics during the 1950's, especially by President Eisenhower, who warned against the "military industrial complex" in his final days in office. Coupled with this mistrust was an equally widespread public faith in private enterprise which, through the mechanism of a free market, was thought the best guarantor of economic security and a free society. On this usually bi-partisan ideological foundation, and partly in reaction to the alleged excesses of the New Deal, Federal policy (enforced by the Bureau of the Budget and its successor, the Office of Management and Budget, est. 1970) required that the Government acquire its goods and services from the private sector. What became known as Federal acquisitions policy was translated into the dense forest of regulations and procedures governing "contracting out." For an excellent and brief discussion of the NASA acquisition process, see Arnold S. Levine, *Managing NASA in the Apollo Era*, NASA SP-4102 (Washington, D.C.: 1982), Chapter 4. For background see Danhof, *Government Contracting*, and Peck and Scherer, *The Weapons Acquisitions Process*, loc. cit.

Congress a political constituency with a material interest in the health--and management--of the space program.

It's impossible to exaggerate the significance of the policy of "contracting out" for the way NASA went about its daily work. Virtually every aspect of the agency's business was ensnared in the dense forest of regulations and procedures of Federal acquisitions policy. The number of procurement actions processed by NASA quadrupled from roughly 44 thousand in 1960 to almost 190 thousand in 1963; by 1965, NASA was processing and monitoring almost 300 thousand contracts, or almost seven times the contracts the agency was managing only 5 years before. The dollar value of the average NASA contract more than doubled as well. However, during the same period NASA's personnel increased by only a factor of three, and only a fraction of those personnel were qualified to manage or monitor contractors. Thus, the burden of implementing the Government's "contract out" policy was borne increasingly by NASA's technical people.

The enormous expansion of contracting out and procurement procedures was not the only by-product of NASA's mobilization for Apollo. Advanced technology for national defense has dominated the Federal Government's support of research and technology, and it was the military's approach to managing weapons research and development that led to the managerial device of the R&D "project" and "program." The project (the development of a single entity or system) and the program (a cluster of interrelated projects) became, in effect, products and product lines marketed by the military to the Congress and the White House.

NASA learned that the Congress, normally stingy with funds for abstract and indefinite activities like fundamental research, could be rallied to generosity when presented with a clearly defined package of concrete tasks with specific missions. The Apollo program, like the Manhattan Project before it, was just such a package. Thus emerged the <u>program</u> as the managerial and budgetary device for executing the agency's broadly framed mission to explore space and advance aeronautical technology.[9] The design and execution of a successful project became the measure of success, and all of NASA's people got caught up in the annual need to market the agency's projects and programs to the Congress in order to obtain the appropriations necessary to maintain themselves.

DEMOBILIZATION

As more than 13,000 NASA engineers worked at their daily routines during the mid-1960's, pursuing the adventure to which President Kennedy had summoned them, the solid ground of common national purpose had already began to shift ominously under their feet. American violence at home, as race-related riots spread from urban ghetto to urban ghetto, was matched by American violence abroad. By 1965, John F. Kennedy lay buried, and 3 years later he would be joined by Robert Kennedy; they, and Martin Luther King, would also be victims of violence.

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[9] The NACA's more modest aeronautical research role--the "service" it provided the military and aviation industry--was rapidly replaced by the NASA's need to direct its research and development know-how to specific projects or programs, in particular, the manned spaceflight sequence known as the Mercury, Gemini and Apollo projects. Conceptually and administratively, the NASA program became the umbrella under which projects were justified and planned, congressional authorization and appropriations obtained, private sector sources solicited and evaluated, contract awards made, and those contracts administered.

Television, which had been acquired by 94 percent of all American households by the mid-1960's, rendered these scenes of violence commonplace and provided a world stage for an outpouring of public protest against U.S. military involvement in Vietnam.[10] In March of 1968, that champion of space exploration, President Lyndon B. Johnson--so tough in the battle against the North Vietnamese, so tough in the battle against poverty and race discrimination--formally abandoned any hope of reelection.

Raising the specter of runaway inflation as costs for the war in Vietnam and the social programs of the "Great Society" mounted, Johnson's economic advisors persuaded the President in 1965 that the budget for the space program would have to be contained. For an ambitious space program to follow the Apollo adventure, there was diminishing enthusiasm outside NASA. In fiscal year 1966, NASA's budget began its downward slide (though actual expenditures for 1966 were the highest of the decade).[11]

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[10] For one view of the decade, see Allen J. Matusow, *The Unraveling of America: A History of Liberalism in the 1960's* (New York: Harper & Row, 1984).

[11] Robert A. Divine, "Lyndon B. Johnson and the Politics of Space," in Robert A. Divine, ed., *The Johnson Years: Vietnam, the Environment, and Science*, Vol. II (University Press of Kansas, 1987), pp.217-253.

As public support for the civilian space program remained soft,[12] the number of government employees NASA was able to support continued its steady decline to about two-thirds (in 1988) of the almost 36,000 people on the NASA payroll in 1966.[13] Faced with deteriorating support, NASA executives had a legitimate desire to protect the centers, whose most skilled technical employees were essential to the agency's ability to go about its work. By designating "roles and missions" for each of the centers, NASA attempted to avoid duplication and assure each installation essential functions related to the particular project work assigned to it.[14]

But the elaborate institutional machinery developed to carry out Apollo could not be so easily disassembled, given the

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[12] As measured by NASA appropriations, which haven't recovered their 1965 level in constant dollars. See also "Towards A New Era in Space: Realigning Policies to New Realities," Committee on Space Policy, National Academy of Sciences and National Academy of Engineering (National Academy Press: Washington, D.C., 1988).

[13] NASA contractor employees outnumbered civil servants 3 to 1 in the early 1960's, ballooned to 10 to 1 in 1966, and subsided to about 2 to 1 in the 1980's. Jane Van Nimmen and Leonard C. Bruno with Robert L. Rosholt, *NASA Historical Data Book: NASA Resources, 1958-1968*, Vol. I, SP-4012 (Washington, DC: National Aeronautics and Space Administration, 1988), p. 118 and *NASA Pocket Statistics* (Washington, D.C.: National Aeronautics and Space Administration, 1986), p. C-27. Numbers of contractor employees can only be estimated.

[14] Part of the intent of the "roles and missions" concept may have been to reduce intercenter rivalry, but institutional specialization has apparently done little to relieve institutional particularism.

interlocking interests it created among NASA's installations, contractors, and geographic regions represented in Washington.

SCIENTISTS, ENGINEERS AND MANAGERS

Conventional wisdom in the 1950's and 1960's believed that successful technology was a linear by-product of scientific research: engineers apply what scientists discover.[15] However, if we believe the many NASA engineers whom our office has interviewed over the past 5 years, distinctions between scientists, engineers, and managers have played an important role in NASA's organizational culture.

Distinguishing NASA scientists and engineers by the actual occupations they pursue, NASA scientists were outnumbered by NASA engineers 26 to 1 in the agency's first 2 years. By the end of the decade, the ratio had declined dramatically--NASA employing one scientist for every eight engineers.

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[15] Numerous studies have questioned this view, maintaining that engineering innovation often occurs independently of advances in the scientific laboratory. See Richard R. Nelson, "The Economics of Invention: A Survey of the Literature," *The Journal of Business*, Vol. 32, No. 2 (April, 1959), 101-27; Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsight: A Defense Department Study of the Utility of Research," *Science*, Vol. 156 (June 23, 1967), 1571-77; Illinois Institute of Technology Research Institute, *Technology in Retrospect and Critical Events in Science*, Report to the National Science Foundation (Chicago: Illinois Institute of Technology Research Institute, 1968); See also: Daniel S. Greenberg, *The Politics of Pure Science* (New York: New American Library, 1967); Don K. Price, *The Scientific Estate* (Cambridge, Mass.: Harvard University Press, 1965); Amitai Etzioni and Clyde Nunn, "The Public Appreciation of Science in Contemporary America," *Daedalus*, Vol. 103, No. 3 (Summer, 1974), 191-205; Theodore Roszak, "The Monster and the Titan: Science, Knowledge and Gnosis," *Daedalus*, Vol. 103, No. 3 (Summer, 1974), 17-32; Sylvia Doughty Fries, "Expertise Against Politics: Technology as Ideology on Capitol Hill, 1966-1972," *Science, Technology & Human Values*, Vol. 8, No. 2 (Spring, 1983), 6-15; and Sylvia D. Fries, "The Ideology of Science during the Nixon Years: 1970-76," *Social Studies of Science*, Vol. 14, No. 3 (August, 1984), 323-341.

When talking about the differences between themselves and scientists, NASA engineers frequently suggest that the difference has mostly to do with "status."[16] Such distinctions persist because professional associations and the academic community distribute the credentials for the modern professions. In so doing, all modern professions still perpetuate the notion, which goes back in Western civilization to Greek and Roman antiquity, that those who work with ideas have a greater social importance than those who work with things.

Professions attempt to control "standards" and economic security, not only by limiting access (typically through credentialing), but by regulating upward movement through definitions of "success." Notwithstanding their many differences, management and engineering share with all professions an inclination to attach status to the degree of remoteness from practical or technical concerns. In this they echo a long-standing prejudice. For management, increased remoteness from practical

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[16] NASA engineers either see themselves as inferior--either by virtue of lesser intellect or status--members of the "scientist and engineer" coupling in the space program; or they assert that, in fact, they are <u>really</u> scientists; or they conclude that distinctions between the two are but artificial, dissolving in the crucible of "research." Data based on two series of interviews conducted by the NASA history office, 1984-1989: with 51 randomly selected NASA engineers, and with 25 former NASA program and project managers.

concerns is reinforced by the typically hierarchical and centralized structure of power in most organizations.

For most NASA engineers, however, occupation diverged increasingly from vocation as they began to spend more of their days doing work for which they had little natural inclination. Because most personnel systems (certainly the Federal Government's) are designed by management to reward increased managerial responsibility, to "get ahead" or "move up" in the modern organization is to move into management.[17]

More than four-fifths of the NASA engineers recruited during NASA's first decade have gone into management positions, and among the older engineers who were employed with NASA or the NACA before 1960, over 90% are in management positions. There are a few cases when the "dual track" career ladder has worked, and an engineer has risen to

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[17] At GS-13, under the Federal Government's personnel classification system instituted in 1979 during the presidency of Jimmy Carter, NASA engineers typically face entering management or staying at GS-13, contenting themselves with periodic cost-of-living and performance based raises. An alternate "merit pay" series, up through GM-15, encompasses management and supervisory positions for which promotions are based on periodic performance evaluations rather than automatic serial pay increases. For commentary on management as a dimension of the careers and professional identity of engineers, see Edwin T. Layton, Jr., *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession*, 2nd ed. (Baltimore: The Johns Hopkins University Press, 1986), especially Chapter I; Robert Zussman, *Mechanics of the Middle Class: Work and Politics Among American Engineers* (Berkeley: University of California Press, 1985), pp. 151-54, 140-45; and [Perucci].

the level of GS-16 without moving into management, but those instances are rare.

During our many interviews, NASA engineers have told us that the "twin-track" (dual-career) ladder doesn't work. Only at Goddard Space Flight Center did an engineer we interviewed vouch for a successful dual-career ladder but, he admitted, the "standard's pretty high."

In science, professional standing is normally independent from one's rank in an organization's hierarchy. "Achievement" is defined and acknowledged by professional peers, and it is the judgment of peers that controls access to the "top" of the profession. Ascent on the technical ladder was, and probably remains, difficult for NASA engineers because the measures of achievement that signify whether they are worthy of ascent derive from a profession--science--that places a premium on novelty, e.g., "patents" and "new theories," which is understood to be the result of intellectual rather than practical preoccupations.

Some of NASA's engineers, alert to the problem of obsolescence in engineering careers, consider management a legitimate and productive alternative for engineers who have accumulated some understanding of how technical programs work. Most recognize that there is a qualitative difference between "good" engineering and "good" management, and that a system that rewards good engineering with a promotion into a management position risks promoting ill-equipped managers. Many engineers with whom we talked insisted that engineers, by inclination and experience, are not natural managers. And because most of those whom we interviewed have become managers, that they think so suggests that "moving up" has meant a struggle to adapt to careers for which they have little interior motivation, other than the desire to get ahead.

Unfortunately, a gift for engineering doesn't necessarily translate into the general outlook managers need to flex with the unpredictable, the persistent fact of life in organizations. A proclivity toward meddlesome management--an inability to delegate--does not, however, seem to be the largest problem facing engineers as prospective managers. The problem that casts the largest shadow over these engineers-turned-managers is the problem of temperament, about which they are both explicit and articulate: "Engineers got into engineering because they didn't like to deal with people," is one fairly typical remark.[18]

Still, a few of the NASA managers with whom we spoke confessed to enjoying management. Those who enjoy managing do so for reasons that range from the challenge of working effectively with people to the psychic and monetary rewards of managerial power and status. If management offers the satisfaction of working creatively through others, it also offers some relief from the powerlessness often felt by those who are typically at the receiving end of an organization's directives.[19]

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[18] Quotation from interview with a senior executive and former engineer at Goddard Space Flight Center. Few things unite American engineers trained in the 1940's and 1950's so much as the narrowly technical focus of their education. Time and again NASA's Apollo era engineers confessed in interviews to having tried to avoid curricula that required grappling with literature, or philosophy, or history. A narrow technical curriculum, already pressured by the rapid growth of sheer technical information to be absorbed, became separated from the study of the natural and physical sciences as well. See Donnell W. Dutton, "A Brief History of Aerospace Engineering Education and Curriculum Changes," January, 1982 (NHO).

[19] Top executives will dispute whether they have much real power over events; but it is the perception of greater authority and status that matters. Because the authority that an engineer has depends as much on the currency of his or her technical knowledge as on simple talent, that authority declines with the onset of obsolescence (unless, of course, an engineer manages to remain current while working). But a manager's authority is cumulative, and authority for the manager typically increases the longer he or she manages, learning to "work" an organization's administrative procedures, personalities, and clientele.

CODA

There is an old saw about dancing dogs. It goes like this: the miracle of the dog dancing is not that he does it so well, but that he does it at all.

The good news about NASA is that, in spite of the constraints of its institutional history, it performs as well as it does. Some of those constraints have been externally imposed--Federal administrative centralization, the procurement system; and some are endemic to any large organization's natural evolution--stresses between technical people and management people, the temptation to let selling to the customer get ahead of actually serving the customer.

In the 1970's, NASA bravely gathered up its marbles and rolled again with the Shuttle. Intelligent and well-informed people will disagree whether that was a good turn to take. I believe it's simply too soon to tell. Pronouncing on the Shuttle now is like pronouncing on the airplane in 1930. One thing is for certain: the fact that a debate over the cost-effectiveness of the Shuttle erupted after the *Challenger* accident didn't contribute to clear public discussion either about the Shuttle, or about the risks of space travel.

Space Station Freedom, Voyager, COBE, the Hubble Telescope--all represent enormous leaps of faith, a sure sign of organizational vitality. And the ability to adapt to a changing environment by reworking the design of the Space Station is, in my judgme ... institutional maturity.

The ... in his book *How to* ... *e*,[20] reminds us tha ... ıcts; they sell them ... institutional self ... we historians travel), the health ... whether the agency thrives.

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[20] Ballantine Books, 1988.